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Carbon emissions from power sector in Pakistan and opportunities to mitigate those

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ABSTRACT

Many developing countries are acutely vulnerable to global climate changes. Pakistan ranks amongst the top of those nations where vulnerability index due to climate changes is very high. Though many of these are not major contributors to the Green House Gases (GHGs) emissions, yet they have adequate potential to mitigate GHGs in various sectors. The power sector, for instance, is one of the major contributors to GHGs in Pakistan and has prospects of abating GHGs by undertaking alternative and improving measures. The GHG contribution from grid connected power plants can be estimated through baseline emissions factor. This paper has calculated this baseline emission factor by determining annual fossil fuel consumption in the grid connected power plants, their net efficiencies, energy outputs and carbon emissions from each fuel source. The data in this regard has been collected from Pakistan Energy Year Book published in 2009, 2010 and 2011 and through related government agencies. The tools, procedures and methodologies of Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) are followed in this regard. The paper has calculated that the weighted average baseline emissions factor for power sector in Pakistan is 0.566 tCO_2/MWh (tons of carbon dioxide per megawatt hour) for wind and solar power projects and 0.478 tCO_2/MWh for hydro power projects excluding Karachi Electric Supply Company (KESC) grid and 0.606 tCO_2/MWh for wind and solar power projects and 0.505 tCO_2/MWh for hydro by including KESC grid. This baseline emissions factor is also a determinant of the amount of Certified Emission Reductions (CERs) that can be accrued by implementing clean Alternative and Renewable Energy (ARE) projects. The amount of CERs generated by an ARE project also have the prospects to earn the carbon revenue streams. The paper has also suggested measures for mitigating grid emissions.

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1. Introduction

Mitigating GHG emissions is now an accepted imperative measure for many countries and Pakistan is no exception. Yet for many countries the cost of mitigation is not fully covered by ordinary financial returns and thus climate finance instruments such as the Clean Development Mechanism (CDM), Nationally Appropriate Mitigation Actions (NAMAs), etc. can be important tool in increasing the penetration of mitigation technologies and practices. Yet, the cost of complying with climate finance provisions can be expensive. This paper seeks to reduce the cost of developing energy related mitigation projects in Pakistan and increasing the reliability of emission reduction estimates by developing an accepted grid emission factor that can be subsequently used by projects.

The burning of carbon based fossil fuels causes the emissions of CO_2 and other pollutants including particulate matter (PM) that contributes to climate change [1]. Globally, fossil fuels such as oil, coal and natural gas are the main source of meeting energy needs of industries and households. The energy sector is responsible for about 3/4 of the carbon dioxide emissions, 1/5 of the methane emissions and a large quantity of nitrous oxide [2].

The scenario of determining the emissions from all gases, sector and source categories per unit of electricity produced is termed as the baseline scenario as per the Marrakesh Accord (MA). The level of GHG emissions that would occur in the absence of a clean energy project is also considered as the baseline scenario [3]. This baseline scenario determines the potential of GHG abatement and capacity to generate CERs by setting up clean project emissions [4]. The generated CERs are a tradable commodity as defined by the Kyoto Protocol and UNFCCC that gives additional capital flows into developing countries like Pakistan, accelerates technology transfer, and enables developing countries to leapfrog to cleaner technologies [5]. Simple mathematical calculations indicate that the higher the baseline emission factor, the higher number of CERs can be generated from a clean energy project. The developed countries are eager to finance the clean energy projects in the developing countries with an intention to meet their emission reduction commitments under the Kyoto Protocol [5]. However the standardized and updated baseline emissions scenario for the power sector in many developing countries is not established. This reduces the ability of the projects to claim the number of CERs that project can earn while going through the validation and verification processes of UNFCCC.

In Pakistan, several projects have developed their own baseline grid emission factor and have successfully got registered their projects with CDM Executive Board. However, a standardized grid baseline emission factor for the country is not available that compels every project developer to calculate its own grid baseline emission factor, thereby causing financial impact and time delays. This paper has addressed this matter by calculating a standardized and updated baseline emission factor following international tools and procedures for Pakistan. Simple O&M method was used to calculate the baseline emission factor as it was determined that the method was more pertinent to grid system of Pakistan since low-cost/must-run resources constitute less than 50% of total grid generation. This baseline emissions factor would enable the developed countries to know their potential of meeting emission reduction commitments by financing projects in Pakistan. This would also help Pakistan in initiating, propagating and promoting the clean energy initiatives under the set of regimes that may be announced in future.

2. Area under study

Pakistan is located in the temperate zone, near to the tropic of cancer having climate varying from tropical to temperate. The coastal south has the arid conditions usually warm, having a monsoon season with adequate rainfall and a dry season with lesser rainfall. The rainfall pattern has remarkable variations throughout the country as it varies from less than 10 in. a year to over 150 in. a year, in different parts [6]. The North part, categorically, the Karakoram range and other mountains of the far north remain cold round the year and the frozen snow keep covering the ridges.

The country has very hot summer and very cold winter. The geographical features of the country are diverse; the country consists of high mountains (mountains systems in the North, center, North-West and South-West), plateaus in the center, and South-West, planes, deserts and a long coastline. Each geographic location is characterized with different climatic conditions; some regions are very cold and some are very hot while some of them remain moderate year round. However, the historical data indicates that the precipitation in this region is also less as compared to adjoining areas. The country is blessed with a river water system which is main source of meeting water requirements for the agriculture [6].

Because of diverse climatic conditions, the vulnerability index of climate change in Pakistan is very high as compared to most of the countries around the globe. In recent years, the country has faced climatic changes like increase in temperature, change in precipitation pattern, weather shift, occurrence of floods earthquakes, etc. Pakistan, though not a major contributor to the emissions that have resulted in creating climate change situation, but owing to its high vulnerability index, the requirement for its adaptation to new changes is very high [7].

Energy and agriculture sectors are the two main contributors in GHG emissions in Pakistan [8]. Curtailments can be made in these sectors to reduce the emissions. Especially, power sector in Pakistan is contributing more in GHG emissions. Switching to clean fuels and deployment of renewable energies to meet energy needs and adoption of energy efficiency measures are regarded as significant factors and key safeguard against the GHG emissions.

Alternative and renewable energy (ARE) resources like wind, solar, small hydro, geothermal tidal/wave, biomass/biogas, etc. are abundantly available in Pakistan and regarded as best in the region. Alternative fuels like biodiesel also has the potential for development in the country. Being clean in nature, the AREs are not only the source of electricity generation but can also result in reducing the GHG emissions. Energy efficiency measures in power generation can also result in reducing GHG emissions.

The GHG abatement potential of AREs and energy efficiency measures render excellent opportunity to earn CERs that can be translated into additional financial income stream coming to the revenues of those projects. The potential of clean ARE/energy efficiency project to earn CERs can be best estimated by a credible baseline grid emission factor [4]. The baseline grid emission factor calculated in this paper will be a key source for estimating GHG emission abatement potential of ARE and energy efficiency projects that would be executed in the country.

2.1. Power sector and GHG emissions

Pakistan's power grid at distribution level i.e., 132 kV and below is being managed by two integrated public sector power utilities i.e., nine Distribution Companies (DISCOs) in public sector administratively controlled by Pakistan Electric Power Company (PEPCO) and Karachi Electric Supply Corporation (KESC) in the private sector. DISCOs supply power to the whole of Pakistan except the metropolitan city of Karachi, which is supplied by KESC [9]. The system of DISCOs and KESC are interconnected through 220 kV double circuit transmission lines [10]. The transmission grid all over Pakistan except the Karachi Metropolitan city is being managed by National Transmission and Despacth Company (NTDC), a federal entity.

Table 1
Installed electricity generation capacity (source: NEPRA)[11].

Type	MW	%
Hydel – WAPDA	6587	27.86
Thermal – WAPDA	4720	19.96
Thermal KESC	2381	10.07
Thermal IPPs	8560	36.20
Hydel IPPs	129	0.55
Nuclear	787	3.33
Rental	374	1.58
Others (renewable)	106	0.45
Total	**23,644**	**100.00**

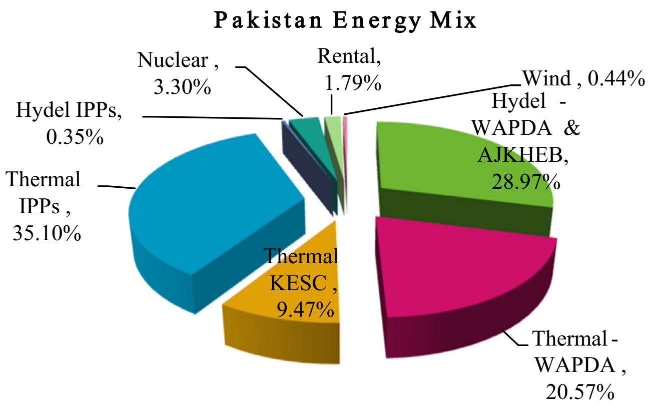

Fig. 1. Electricity mix of Pakistan for the year 2011–12 [11].
Source: NEPRA.

The national electricity mix in Pakistan includes hydro, thermal and nuclear power plants. About 28.40 percent power is generated through hydel power plants, 67.82 percent through thermal power plants and the rest 3.78 percent is generated through nuclear and renewable power generation systems [11]. The detail of installed electricity generation capacity in Pakistan is given in Table 1 and Fig. 1.

The data available with the respective government departments indicate that Pakistan's current total installed capacity for grid power supplies is 23,644 MW. The suppressed electricity demand in the country is 19,735 MW during summer and 14,922 MW during winter season.

The captive power plant statistics indicate that at present 42% of the manufacturing businesses have installed costly captive power units [12]. The approximate capacity of these captive power plants is around 2000 MW.[1] The captive gensets installed in residential sector are not accounted for. Also, a large number of UPS systems are operating in the country which also put additional burden to the national grid. The figures of statistical department indicated that Pakistan's fossil fuel Import bill for the year 2011 had remained $13+Billion which is 70% of the total Export Earnings of the country [13]. Asian Development Bank has estimated that with current percent increase in energy demand, the oil import bill expected to reach at level of US $ 28 billion by 2015 which is 200% of the National Export Earnings.[2]

Despite addition of more than 3000 MW in last five years,[3] the supply side has not been developed to that extent that it could suffice power requirements of the existing connected load. There is around 3000–5000 MW Demand Supply Gap which is resulting in 4–12 h Load Shedding in urban and rural areas of the country [14].

Owing to heavy reliance on thermal power plants, the power sector is one of the major contributors to GHG emissions. Energy sector and especially the power sector has remained the major contributor to GHG emissions with around 50% share [14].

2.2. Peak electricity demand and supply projections

The electricity demand projections as per the studies of the PEPCO and Planning and Development Division indicate that Pakistan is short of electricity projected demand electricity. Chart given in Fig. 2 below indicate that the installed capacity of Pakistan in 2013–14 should have been 34,927 MW, whereas, current installed capacity is 23,823 MW that indicates shortage of 11,104 MW. The planned installed capacity for 2019–20 is 63,000 MW which requires commissioning of 39,177 MW more power by 2020.

2.3. Future plans of government of Pakistan to meet project

The Government of Pakistan (GoP) is exploring every energy resource to meet energy needs of the country. Generation of power from ARE resources (like wind, solar, small hydro, biomass/waste to energy, etc.) and imported and local coal has been visualized as a short term solution to current energy crises. While exploiting ARE and coal resources more, the GoP is also harnessing hydro and nuclear power in the medium and longer term.

3. Baseline carbon emissions from power sector

Baseline emission scenario is very prudent to determine when it is required to calculate total emissions of GHGs from the sector and strategize to reduce or abate those emissions [15]. Globally, power sector is considered as major source of GHG emissions in most of the countries because of higher reliability on fossil fuel based thermal power generation [16–18]. The overall global electricity generation mix indicates that share of thermal power generation is 70.5% i.e., coal (51.5%), followed by gas (16%), and oil (3%) [19]. By deploying cleaner energy technologies like ARE, it is possible that GHG emissions can be possibly reduced [20]. In order to make an energy policy with a target to reduce GHG emissions and devising an environmental strategy to undertake GHG mitigation activities, it is prudent to accurately forecast GHG emissions from fossil fuel power plants [21]. The accurate forecasting of carbon dioxide (CO_2) emissions from fossil fuel energy consumption is a key requirement for making energy policy and environmental strategy [22].

UNFCCC is emphasizing that all countries to undertake increased mitigation efforts and commit targets for emissions reductions [23]. Though, the developed nations are planning to invest more in GHG emissions reduction initiatives, there is a potential to reduce large quantum of GHG emissions if major GHG emissions contributing sectors in the developing countries like Pakistan are encouraged to shift to ARE technologies [24]. The countries of the region like India, China, Thailand, Malaysia, Indonesia, Iran, etc. have taken several initiatives to harness ARE technologies and contribute towards mitigating GHGs. Most of the countries of the world have established baseline emissions factor and accordingly devising policies and strategies to bring the emissions level down from the baseline.

At present, the national baseline carbon emission factor for Pakistan is not determined. Under the scope of this paper, data has

[1] http://pakbiz.com/news/Inefficient_captive_power_plants_causing_loss_of_Rs70bn_nid862386.html.
[2] Integrated Energy Sector Recovery Report and Plan, June 2010, FODP Energy Task Force.
[3] http://www.dailytimes.com.pk/default.asp?page=2012\10\31\story_31-10-2012_pg5_13.

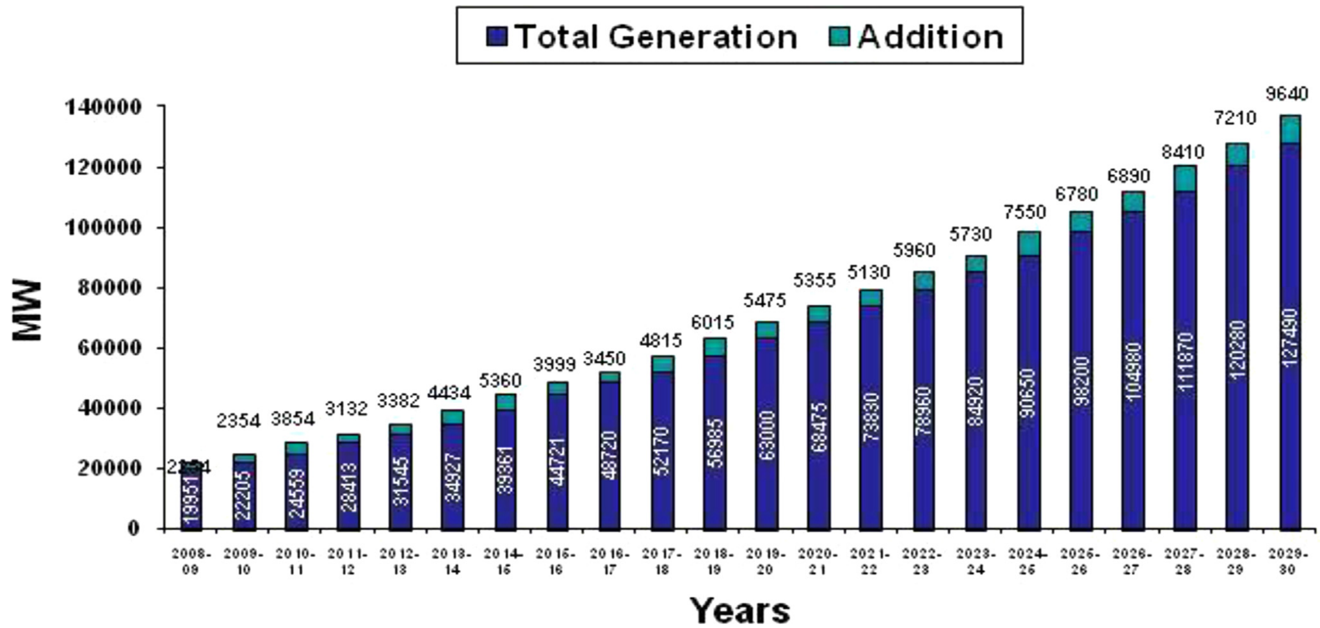

Fig. 2. Electricity supply projections 2009–2030 (PEPCO & KESC (Combined System)).
Source: PEPCO, P&D Div.

been collected and analysis has been made regarding power generation plants in Pakistan, their efficiencies and fuel consumptions to determine baseline emission factor of the country. This emission factor can be used by the power plants while developing their project documents and calculating the ability of the plant to generate CERs under CDM [5]. This work can be helpful in reducing the time that the project owners have to spend while establishing the baseline scenario.

4. Materials and methods

Data collection was the first important task for this research. The input data for calculation of the base line emissions factor includes the electricity generation from each fuel type, total fuel consumption, Low Heating Values (LHV), Gross Calorific Values (GCV) of each fuel and Effective CO_2 Emissions Factor of each fuel. The values for the electricity generation from each fuel type, total annual fuel consumption and GCV are taken from Pakistan's Energy Year Book for the years 2009, 2010 and 2011 published by Hydrocarbon Development Institute of Pakistan (HDIP) [25], whereas the values for LHV and Effective CO_2 Emission Factor of each fuel are taken from the IPCC methodologies published in 2006.

The number of CERs by a project is regarded as the quantum of Carbon Credits that the project can earn as per UNFCCC guidelines. These Carbon Credits can then be sold to international carbon markets and earn revenue. The financial return gained through this can help in reducing the technical, technological and financial barriers in executing such projects [9,26].

4.1. *Procedure to determine baseline emission factor*

The calculations for determining the baseline emission factor were carried out based upon the two methodological tools of CDM Executive Board [27,28]. Following six steps were undertaken while calculating the Baseline Emission Factor as per IPCC methodologies:

Step 1: Identify the relevant electric power system.
Step 2: Select an operating margin (OM) method.
Step 3: Calculate the operating margin emission factor according to the selected method.
Step 4: Identify the cohort of power units to be included in the build margin (BM).
Step 5: Calculate the build margin emission factor.
Step 6: Calculate the combined margin (CM) emissions factor.

The details of these steps are further described below as follows:

Step 1: *Identify the relevant electric power system*:
As a first step, the electricity system connected to the power plants all over the country was defined. The boundary was fixed for whole of Pakistan. While doing so, it was noted that the grid operations at all levels in Karachi Metropolitan city are being managed and operated by KESC which is a private sector entity and rest of Pakistan is being managed and operated by PEPCO through nine public sector DISCOs as described in Section 2.1 above. KESC is an independent organization that is responsible for generation and distribution of electricity within the Karachi Metropolitan city territory. Main electricity generation within KESC grid comes from natural gas (NG) and high speed diesel (HSD) based thermal power plants. The KESC is also being supplied with 700 MW through the NTDC grid. The electricity supplies to NTDC grid is being generated through various fuels like fossil fuels (i.e., Refused Fuel Oil (RFO), HSD and NG), hydel, nuclear, coal, etc. [9,11,13]. Since, the electricity supplies to KESC grid system and NTDC/DISCOs system have different fuel mix and as both are parallel integrated entities in this paper two scenarios have been visualized to calculate the grid emissions factor for Pakistan (i) electric power system with KESC grid and (ii) electric power system without KESC grid.
Step 2: *Select an operating margin (OM) method*:
Taking into account the grid system in Pakistan, current energy scenario in the country and the data collected for net electricity generation and fuel consumption, the simple OM method has been used for calculation of the operating margin emission factor ($EF_{grid,OM,y}$). This resulted in determining the CO_2

emissions factor(s) for net electricity (EF_{grid}) on the grid from a connected electricity system within the country.

Step 3: *Calculate the operating margin emissions factor according to the selected method:*

The simple OM emissions factor is calculated as the generation-weighted average CO_2 emissions per unit net electricity generation (tCO_2/MWh) of all generating power plants serving the national system, not including low-cost/must run power plants The calculation was done based on data on fuel consumption and net electricity generation of each power plant. Following formula was used to calculate the simple OM emissions factor [22]:

$$EFgrid,\ OMsimple, y = \frac{\sum_{i,m} FCi, m, yXNCVi, yXEFCO_2, i, y}{\sum_m EGm, y} \tag{1}$$

where $EF_{grid,OMsimple,y}$ is simple operating margin CO_2 emissions factor in year y (tCO_2/MWh), $FC_{i,m,y}$ is amount of fossil fuel type i consumed by power plant m in year y (mass or volume units), $NCV_{i,y}$ is Net calorific value (energy content) of fossil fuel type i in year y (Joules(J)/mass or volume unit), $EFCO_{2,i,y}$ is CO_2 emissions factor of fossil fuel type i in year y (tCO_2/Giga Joules (GJ)), $EG_{m,y}$ is net electricity generated and delivered to the grid by power plant/unit m in year y (MWh), m is all power plants serving the grid in year y except low-cost/must-run power plants, i is all fossil fuel types combusted in power plant/unit m in year y, y is either the three most recent years for which data is available at the time calculating baseline emissions factor or the applicable year during monitoring (ex post option).

Two separate scenarios are taken for calculations of Simple OM as indicated in Step 1 above.

The calculation to determine Simple OM includes computing NCV by multiplying the LHV of each fuel by its GCV, Fuel Heat of each fuel by multiplying its NCV with total annual consumption, Grid Emissions from each fuel type by multiplying its Fuel Heat values with Effective CO_2 Emission Factor of each fuel, this value is divided by total electricity generated annually from each fuel to determine Grid Cumulative Emission Factor (CEF) or Simple OM value.

Step 4: *Identify the cohort of power units to be included in the build margin*:

The set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently are taken into account while calculating the emission factor as per the guidelines of IPCC.

Step 5: *Calculate the build margin emission factor*:

The build margin emissions factor is the generation-weighted average emission factor (tCO_2/MWh) of all power units m during the most recent year y for which power generation data is available. This is calculated as follows [22]:

$$EFgrid, BM, y = \frac{\sum_m EGm, yXEF\ EL, m, y}{\sum_m EGm, y} \tag{2}$$

where $EF_{grid,BM,y}$ is Build margin CO_2 emission factor in year y (tCO_2/MWh), $EG_{m,y}$ is net quantity of electricity generated and delivered to the grid by power unit m in year y (MWh), $EF_{EL,m,y}$ is CO_2 emission factor of power unit m in year y (tCO_2/MWh), m is power units included in the build margin, y is most recent historical year for which power generation data is available.

In order to calculate BM, the IPCC guidelines require taking either five recently constructed power plants or 20% of the national generation capacity, whichever is greater. We adopted the latter option as this gives the greater value. The Net Electricity Generation and Plant Efficiencies are taken from Pakistan's Energy Year Book for the years 2009–2011, whereas Emission Factors of each fuel are taken from the IPCC guidelines. The product of generated electricity and Fuel Emission Factor is used to calculate CO_2 Emissions which are then divided by Net Electricity Generation from each plant to calculate Grid Emission Factor and Certified Emission number (CE).

Step 6: *Calculate the combined margin emissions factor*:

The combined margin emissions factor is calculated as follows [22]:

$$EFgrid, CM, y = EFgrid, OM, yXWCMXEFgrid,\ BM, yXWBM \tag{3}$$

where $EF_{grid,CM,y}$ is Combined Margin CO_2 emission factor in year y (tCO_2/MWh), $EF_{grid,BM,y}$ is Build Margin CO_2 emission factor in year y (tCO_2/MWh), $EF_{grid,OM,y}$ is Operating Margin CO_2 emission factor in year y (tCO_2/MWh), w_{OM} is Weighting of Operating Margin emissions factor (%),W_{BM} is Weighting of Build Margin emissions factor (%)

The following default values are to be used for W_{OM} and W_{BM} as per the IPCC guidelines:

- Wind and solar power generation project activities: W_{OM}=0.75 and W_{BM}=0.25 (owing to their intermittent and non-dispatchable nature) for the first crediting period and for subsequent crediting periods.
- All other projects: W_{OM}=0.5 and W_{BM}=0.5 for the first crediting period.

Henceforth, the Simple OM/CEF value calculated in Step 4 above is multiplied with 0.75 and the BM/CE values calculated in Step 5 above are multiplied with 0.25. Both are added to give CM for Wind and Solar. For calculating CM for Hydro, both OM and BM and multiplied with 0.5 and added. The calculations in this regard are given in Tables 2a and 2b.

5. Results and discussions

Based on the calculations (Tables 2a and 2b), it was determined that the weighted average baseline emission factor comes out to be 0.566 tCO_2/MWh for wind and solar power projects and 0.478 tCO_2/MWh for hydro power projects under scenario one i.e., excluding KESC as part of overall grid and under scenario two

Table 2
a National baseline emission factor calculated excluding KESC.

SOM	Year	tCO2/MWh
	2009	0.567
	2010	0.697
	2011	0.696
	Average	**0.653**
BM	**2011**	**0.303**
CM for wind and solar 75%OM 25%BM		**0.566**
CM for Hydro 50–50%		**0.478**

Table 2
b National baseline emission factor calculated including KESC.

SOM	Year	tCO2/MWh
	2009	0.685
	2010	0.704
	2011	0.732
	Average	**0.707**
BM	**2011**	**0.303**
CM for wind and Solar75%BM 25%OM		**0.606**
CM for Hydro 50–50%		**0.505**

Table 3
Calculations for numbers of CERs generation from a 50 MW wind power plant.

Project capacity	50	MW
Benchmark energy	135.00	GWh
Benchmark capacity factor	31%	
No. of hours in a year	8760	Hours
Carbon emission/intensity factor	0.544	
Tariff for wind power project	14.6628	US Cents/kWh
Credit rate in euros	4[a]	Euros
Conversion rate euro to dollar	1.55	Euro/USD
Conversion rate dollar to PKR	90	USD/PKR
Total CERs in 20 years	1,614,161	CERs
Average CERs in 20 years	76,865	CERs
Benchmark CERs	76,410	CERs

[a] EU markt snapshot Aug 2010 – maart. 2012 http://www.emissierechten.nl/ (26 mrt 2012).

Table 4
Calculations for numbers of CERs generation from a 20 MW small hydro power plant.

Project capacity	20	MW
Benchmark energy	102.00	GWh
Benchmark capacity Factor	58%	
No. of hours in a year	8760	Hours
Carbon intensity factor	0.451	
Tariff for hydro power project	8.6244	US Cents/kWh
Credit rate in euros	4[a]	Euros
Conversion rate euro to dollar	1.55	Euro/USD
Conversion rate dollar to PKR	90	USD/PKR
Total CERs in 20 years	1,029,971	CERs
Average CERs in 20 years	49,046	CERs
Benchmark CERs	48,756	CERs

[a] EU Markt Snapshot aug 2010 – maart. 2012 http://www.emissierechten.nl/ (26 mrt 2012).

i.e., with the inclusion of KESC, it comes out to be 0.606 tCO_2/MWh for wind and solar power projects and 0.505 tCO_2/MWh for hydro power projects.

The numbers calculated above indicate that Pakistan's national grid is relatively cleaner, as compared to other countries of the world yet still emits large amounts of CO_2. From the results it can be deduced that there are definite prospects of making the grid cleaner by setting up ARE projects and undertaking certain energy conservation measures that would result in abating the CO_2 emissions. Based upon the baseline emission factor, it can be determined that the clean energy projects generating Z number of MWh having no or very minimal emissions can result in abating $Z \times E_{grid,CM,y}$ tones of CO_2. This number is regarded as number of CERs generated by the project which can be traded in international carbon market under CDM and can become a financial revenue earning stream for the project.

5.1. Anticipated financial returns by generating carbon credits

The baseline emission factor determined above can be directly used to work out the number of CERs that a clean energy project can generate in its whole life. Each CER is also termed as Carbon Credit. This number can then be used to determine the financial returns that can be accrued from sale of CERs in the international carbon market. For instance, assume a 50 MW wind power project able to generate 135 GWh annually on 31% capacity factor. The power plant will be able to generate at an average of 73,440 CERs annually. The details of assumed plant and number of CERs are given in Table 3.

Each generated CER was assigned a value of Euro 4.[4] The calculations indicate that the CERs accrued from ARE power project (wind and solar) can generate a revenue of around Euro 305,640 annually. This is a substantial return which an ARE power project owner can make.

Similarly, a small hydro power plant of 20 MW capacity having capacity factor of 58% will be able to generate around 46,000 CERs annually. The details of assumed plant and number of CERs are given in Table 4.

Supposing similar assumptions as in case of wind, it is deduced that the plant will be able to generate Euro 184,000 annually as carbon revenue.

6. Mitigation and adaptation measures for power sector

Being a developing country, it is very difficult for Pakistan to cut short increasing energy demand and to avoid commissioning of power projects based on conventional energy resources. As a whole, Pakistan is contributing very less in current global climate change, but unfortunately, it is one of the nations who are facing higher degree of vulnerabilities of the phenomenon of climate change. Owing to this, Pakistan's major focus should be adaptation to current climate change. However, there can be a number of mitigation measures which can be undertaken.

Being indigenous and clean source of energy, ARE renders excellent prospects for achieving energy security, self-reliance to meet energy needs, environmental protection and sustainable economic growth. Owing to this ARE shall be given special incentives and preferential growth environment. Moreover, energy conservation, efficiency improvement and mitigation measures can also be undertaken in the power sector to mitigate GHG emissions.

This paper suggests that the GoP should undertake mitigation and adaptation measures to abate GHG emissions and adapt to the current prevailing and future anticipated changing climatic conditions. Most of the measures can result in abating GHGs and an ability to earn CERs/carbon credits through CDM/NAMA or through other international carbon market mechanisms and render opportunity to earn additional revenues, thereby resulting in reducing financial impacts of undertaking such initiatives.

7. Conclusion and recommendations

Power sector in Pakistan is one of major contributors to GHG emissions in the country. The national electricity mix is dominated by thermal power projects emitting large quantity of CO_2. The electricity mix of the country can be improved by reducing the dominance of thermal power plants and making the grid cleaner.

The baseline emissions factor has been determined in this paper for the first time. The baseline emissions factor is a helpful tool in determining the per MWh emissions onto the national grid and ability of a cleaner project to abate the emissions. Having an established and announced baseline carbon emission factor can be very beneficial in terms of giving the project developers an upfront knowledge of what CER numbers can their project generate during whole life of the project and determining the approximate financial returns that their project can earn through sale of CERs. This paper has calculated baseline emissions factor for power sector in Pakistan based upon currently integrated power projects, their efficiencies, fuel consumption and emissions. Based on the calculation it was determined that the weighted average baseline emission factor comes out to be 0.566 tCO_2/MWh for wind and solar power projects and 0.478 tCO_2/MWh for hydro power projects excluding KESC as part of overall grid. With the inclusion of

[4] EU Markt Snapshot aug 2010 – maart. 2012 http://www.emissierechten.nl/ (26 mrt 2012).

KESC, it comes out to be 0.606 tCO_2/MWh for wind and solar power projects and 0.505 tCO_2/MWh for hydro power projects.

This paper has also calculated/anticipated annual GHG abatement and CERs earning potential for an assumed 50 MW wind power and 20 small hydro power projects and expected financial returns that can be earned through sale of CERs. The results indicate that the 50 MW wind power project able to generate 135 GWh annually on 31% capacity factor can earn at an average of 76,410 CERs and Euro 305,640 annually. And a 20 MW small hydro power project able to generate 102 GWh on 58% capacity factor can earn at an average of 48,756 CERs and Euro 184,000 annually

This paper has further emphasized that Pakistan being vulnerable to climate change impact, has to undertake certain initiatives to mitigate as well as adapt to such changes. Pakistan is blessed with ARE potential. The country needs to increase the share of electricity generated through such clean resources. Exploiting ARE will also help in achieving energy security, self-reliance to meet energy needs, environmental protection and sustainable economic growth. The paper suggests that ARE shall be given special incentives and preferential growth environment. National Electric Power Regulatory Authority (NEPRA) shall give special incentives, premiums, higher rate of returns and preferential tariffs to the AREs. In order to encourage the project developers, all the power generated through the ARE projects executed in public and private sector be made obligatory for the DISCOs, Utilities and the NTDC to purchase. Moreover, it shall be obligatory for the Utilities to ensure purchasing at least 10% of power in their mix from ARE projects. Additionally, in order to promote utilization of off grid ARE applications to meet energy needs, special subsidies and buying support packages shall be announced by the Finance Division that would increase the buying capacity of the people. The entire commercial lighting load may be shifted to ARE technologies. The energy needs in the agriculture and industrial sectors may be shifted to AREs in a phase-wise manner. The building structures should also be made energy efficient and maximum utilization of AREs should be made part of Building Codes. The industries may be asked to shift to efficient and state-of-the-art technologies that should result in higher efficiencies, reduced fuel consumption and lower emissions. The older power systems and industries should also be shifted to energy efficient systems.

Such initiatives can not only help in reducing the GHG emissions, but can also render opportunity for self-reliance, energy security and earn financial benefits through sale of CERs in international carbon markets.

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